Atmosphere Tolerant Acquisition, Tracking and Pointing Subsystem

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OUTLINE

- Introduction
- Problem definition
- Our Approaches
- Analysis on beacon fade tolerance
- Conclusion

INTRODUCTION

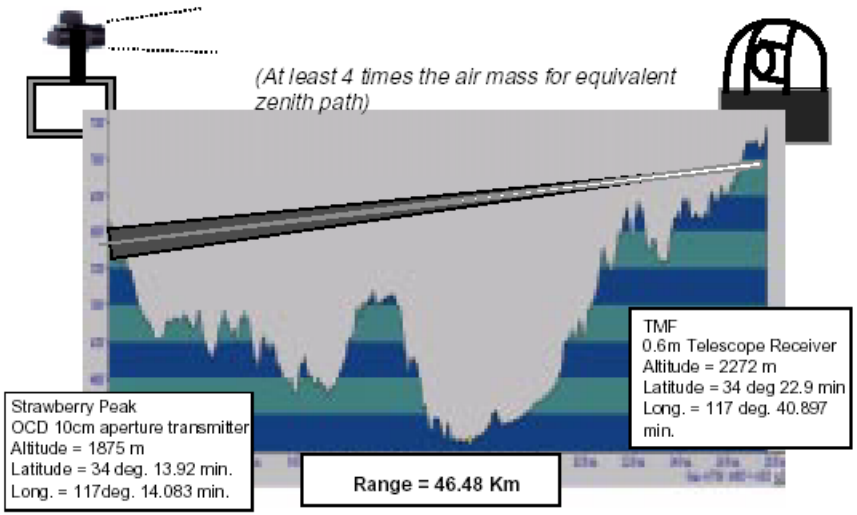
- Atmospheric induced fades affect all three stages (Acquisition, Tracking, and Pointing) of optical communications
  - During acquisition – acquisition failure -> another acquisition procedure (lost time)
  - During Tracking/Pointing – Tracking loss/Mis-pointing beyond allocated error budget

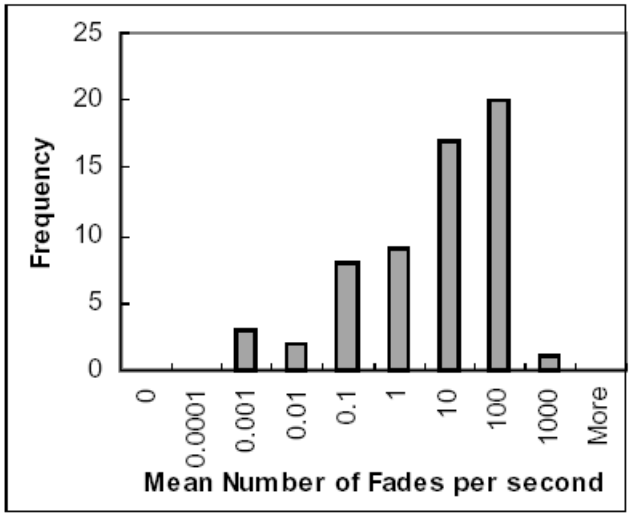
INTRODUCTION-Contd

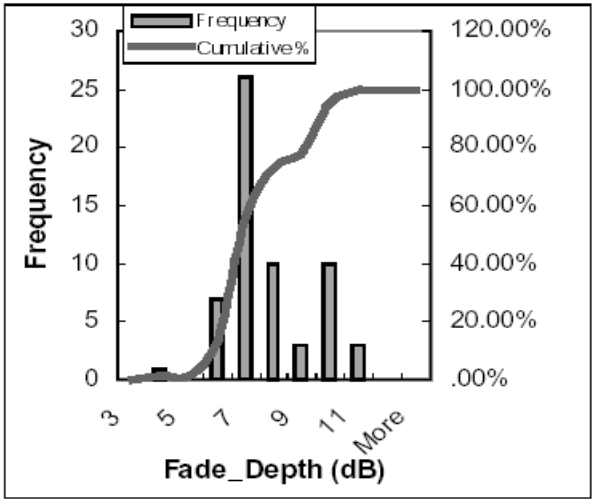
- Fades are generally caused by
  - Atmospheric conditions (scintillations, beam wandering, clouds, rain),
  - Other situations (blocked line-of-sight due to objects, trees, buildings, and etc.).

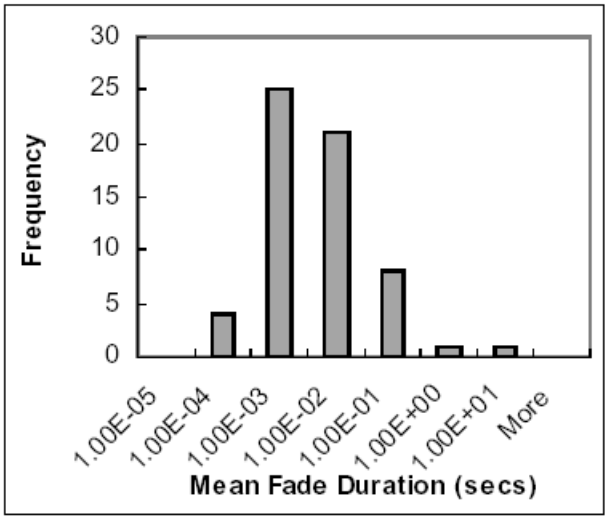
- Fade depth of more than 11dB and mean numbers of fades per second of more than 1000 were observed in the recent Gnd-Gnd optical link demonstrations.

Past Gnd-Gnd Optical Link Demonstration Results

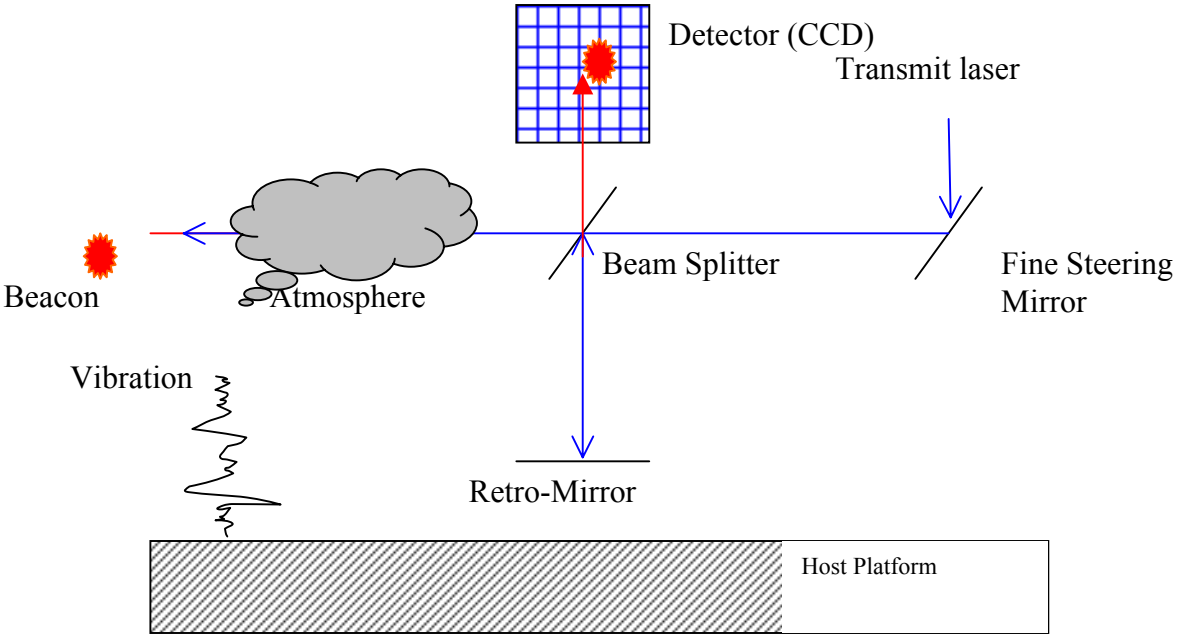








Problem Definition



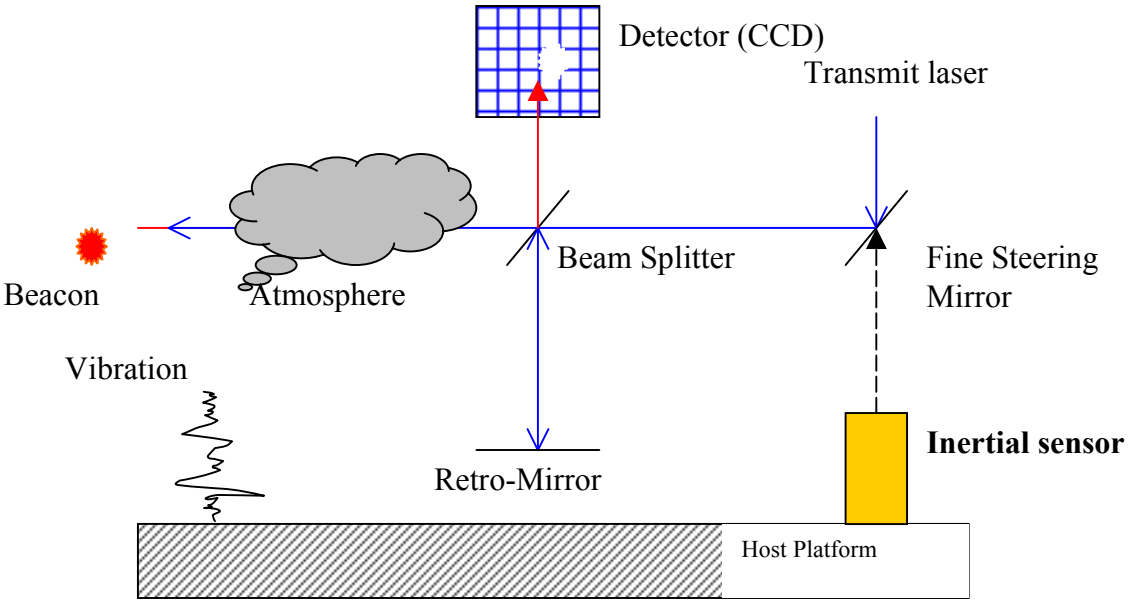
Beacon based ATP System is sensitive to atmospheric induced fades

Problem Definition-Contd

- Acquisition – Fade can cause search failure, resulting in additional search time.

- Tracking/Pointing – Fade causes tracking loss, hence, pointing failure followed by re-acquisition and tracking/pointing. Considerable amount of time can be wasted due to fades.

Our Approaches



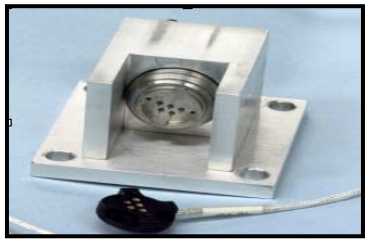
- The pointing information from the beacon beam position from the FPA can be substituted by measuring the relative platform position with respect to the last seen beacon position on the FPA.
- Information from the inertial-sensors is combined with the existing beacon tracking algorithms, which yields a compensating algorithm that provides the necessary pointing information to maintain a stable, uninterrupted optical communications link for a longer period of time than the current state-of-the-art systems.

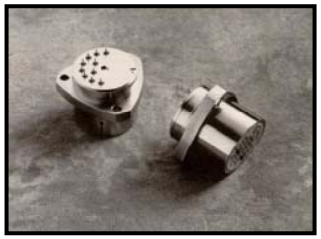
Our Approaches-Contd

- Pros:
  - a) Stable tracking during fades
  - b) Feasible data transmission during fades
  - c) Increased ranges of communication for the same beacon power
  - d) Requires lower beacon power to maintain link for the same range
- Cons:
  - a) Small increase of mass (inertial sensor)
  - b) Increased complexity of the tracking algorithm

Commercially available Inertial Sensors

Type	Gyro (Navigation Grade)	Angle Displacement Sensor (SD-8301)	Angular Rate Sensor (ATA ARS-12)	Accelerometer (Honeywell QA-3000)
Bandwidth	>1 Hz	2-2 kHz	1-1 kHz	1 to 500 Hz
Noise	0.06 μrad	0.03 μrad	0.10 μrad	76 μg
Mass	6.8 ~17 kg	0.3 kg	0.1 kg	0.08 kg
Cost	~$1 million	$70,000/axis	$6,000/axis	$10,000/axis
Power	25 to 50 W	300 mW, max	300 mW, max	280 mW, max
Comments	Bandwidth, mass, power, cost	Long-lead time (2 yr)	Flight-qualified version under development	Flew on Pathfinder, IPEX-I and II



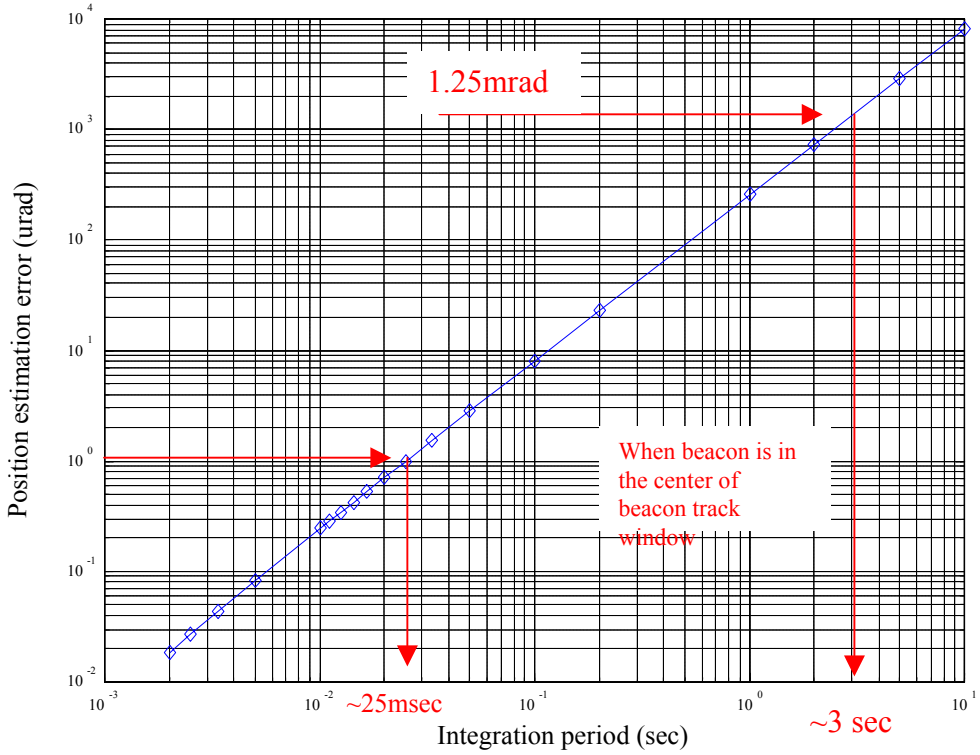


Honeywell QA-3000

Analysis on beacon fade tolerance

- **Determine maximum duration to maintain designed pointing performance using accelerometers**
  - Pointing error budget & Accelerometer performance (rms noise, bias)
- **Determine maximum duration to maintain beacon spot within tracking window when the tracking relies on only accelerometers**
  - Tracking window size & Accelerometer performance (rms noise, bias)

Analysis on beacon fade tolerance-Contd



- Assume Honeywell QA3000 accelerometers
- Used rms noise of 340ug
- Separation of two accelerometers of 15cm
- Double integration of acceleration to get linear displacement estimates
- Zero bias assumed

Angular displacement estimation error vs. duration (integration time)

Benefits of beacon fade tolerance
UAV-Ground example

Max pointing duration vs. pointing error budgets (to maintain pointing)

Pointing error budget	Duration
0.1urad	5.5msec
1urad	25msec
2urad	40msec
3urad	50msec
4urad	60msec
5urad	70msec

Communication link can still be maintained even under longer fade duration, since fade is worse on uplink.

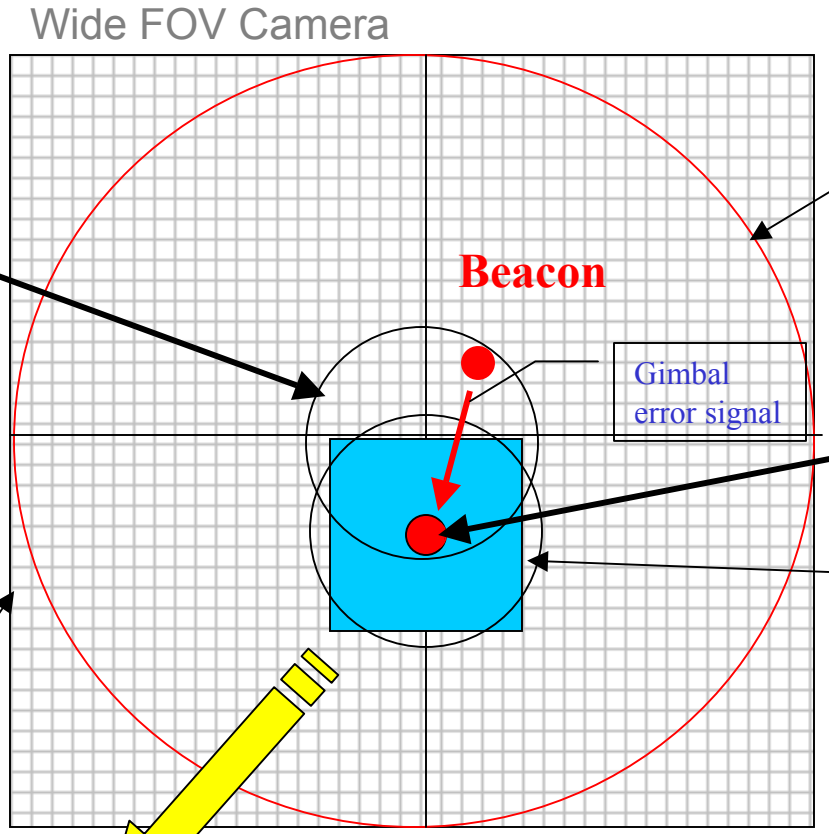
Benefits of beacon fade tolerance - Contd

Max tracking duration vs. accelerometer induced error (to maintain beacon within tracking window)

Accelerometer induced error	Max tracking duration
1.25mrad	~3 sec

Assuming beacon is in the middle of beacon tracking window

UAV Acquisition and Tracking Window



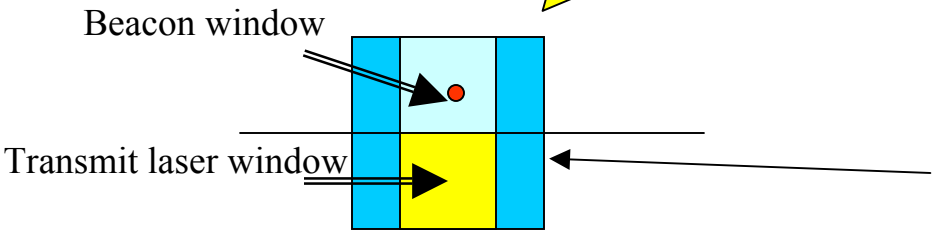
Coarse Pointing Uncertainty
-6mrad, 3σ
-RSS
-Attitude, Position, Gimbal

Acquisition FOV
- 51 mrad diameter

Gimbal points to center of tracking FOV

Tracking Window
- FOV: 5X5 mrad

CCD Footprint
-480x480 pixels
-106.25 µrad/pixel



Tracking Window
- FOV: 5X5 mrad

Conclusion

- Application of inertial sensors to ATP system is effective against beacon fades
- Atmosphere tolerant ATP system's benefits:
  - Robust acquisition procedure
  - Steady tracking/pointing leads to stable communication links
- A key to the tolerance: Inertial sensor performance, Pointing error budget, FOV